More Than One-Way to Catch a Fish: Use of Effective Translation of Ocean Science to Promote Ocean Literacy

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***Abstract*-An understanding and appreciation of the ocean, Great Lakes and coasts' role in our lives (from commerce to recreation to weather) and our interdependence upon them is a chief goal of the Ocean Literacy Initiative. Today most Americans undervalue the ocean because few know and value the vital functions the ocean performs in service to our society and to each of us individually. One requisite for ocean literacy is the promotion of effective life-long learning of these vital functions and services through sustained communication that captures both our hearts and minds. Story development and data translation address one aspect of lifelong learning, the sustained supply of compelling and accurate science and technology stories about the ocean, coasts, and Great Lakes. Stories that educators and communication professionals can incorporate into all types of learning materials. Here we continue our examination of two models (Government Research Enterprise and an Academic Research Organization) that are case studies in developing and identifying highly effective story development and data translation practices.**

I. INTRODUCTION

Our lives are dependent upon the ocean, coasts, and Great Lakes although most do not know it and many others do not fully appreciate the extent of that dependence [1, 2]. For centuries we have undervalued and underappreciated the critical services provided to our society and to our health, wealth, and well-being. We have used these services without attention to their economic and cultural value or to the economic and societal consequences of overuse [3, 4]. To develop an appreciation of the ocean, coasts and Great Lakes and to persuade citizens of their value so that informed and responsible decisions are made over a lifetime, citizens must understand and identify with the functions and services that the ocean, coasts, and Great Lakes provide and be motivated to act to sustain them [5, 6]. The chief goal of the Ocean Literacy Initiative [7] is to develop and then sustain this understanding, appreciation, and motivation over a lifetime. That lifelong journey begins when a citizen's attention has been captured and grows through sustained exposure to stories and activities that engage their hearts and minds. Stories that build upon familiar experiences; link to universal concepts held by all peoples, like concern for health, wealth and well-being; enrich and deepen a citizen's scientific and technological understanding of the ocean, coasts and Great Lakes, and builds their commitment to them [5, 6].

Previously, story development and information translation models were examined to identify key similarities and differences in processes and approaches [8]. In the models examined, it was clear that effective efforts capture an audience's attention, engage the audience in an interactive and participatory way, strive to deepen understanding, and develop an appreciation of personal dependence on the ocean and Great Lakes. The ultimate objective being a behavior change (e.g., engaging in more science based activities or an act of environmental stewardship, pursuing a course of study or career) that stems from the deeper understanding, appreciation, and motivation [8]. The implementation of each model is a case study in development and identification of highly effective practices. Here we present data for two of these models (i.e., University Research Organization and Government Research Enterprise).

In both cases, the model's processes have a spin-up period during which team members learn to work together and complement each other's expertise [8]. One model exhibits a step function response consistent with this spin-up. Finally, we consider how the insights provided by these information translation case studies can be applied to developing and sustaining an effective lifelong ocean literacy campaign.

II. A WHOLE SYSTEM FRAMEWORK

For ocean, coasts, and Great Lakes educators, knowing how to initiate and promulgate improvements within the large and complex system of learning in the U.S. so all are *caught* by the allure of the ocean, is a great challenge. This is doubly difficult because the numbers that must be *caught and reeled-in* are huge. Consequently, efforts that are cost effective on a small-scale may not be scalable to the numbers and financial reality of the full-scale problem. Beginning with a *whole system* vision, breaking the vision into functional parts, and constantly applying a filter for those solutions that both scale-up cost effectively and score high on improvements in output, outcome, and impact leads to investments in educational activities that maximize return-on-investment (i.e., greatest sustained improvements in awareness, appreciation, understanding, motivation, or labor supply for the financial investment). As argued previously [8] data translation and story development is a solution for one part of this *whole system* vision that can scale.

The *whole system* view (Fig. 1) recognizes there are three distinct audiences whose purposes and objectives drive communication: Partner/Peer, Education, and Strategic audiences. In each, the nature of the target audience is fundamentally different: they differ in their *a priori* knowledge, their motivation for acquiring the knowledge, and how they will use it.

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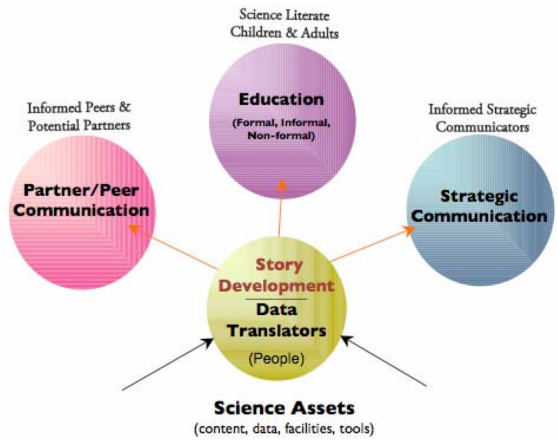

Figure 1. Whole system framework for use of science assets by different audience sectors. Framework is a synthesis of concepts from several fields (communications, public policy, customer service, business process control, organizational management) and the authors' personal experiences.

Partner and Peer audiences have a high degree of knowledge and conceptual understanding about the topic, may be engaged in developing the knowledge, and may be interested in creating or expanding partnerships to do so. *Strategic audiences* have little to no *a priori* knowledge, are relatively unsophisticated information consumers, desire distilled, synopsized information which they use to make or shape key policy, legislative, or business decisions. *Education audiences* sit between these two. The members of this audience vary widely in their *a priori* knowledge and conceptual understanding of a topic and the use of information to develop understanding; some are novices (students and elementary educators) while others (undergraduate faculty) are experts. In all cases, educators strive to capture, sustain, motivate, and deepen awareness, appreciation and conceptual understanding of a topic by youth and adults, within the context of life experiences and careers.

This *whole system* view highlights the importance of continuity and coherency of content between the communication sectors. An examination of one of these sectors, *Education*, reinforces this observation and highlights the importance of content continuity between learning programs within a sector in capturing, sustaining, motivating, and deepening awareness, appreciation, and understanding over a lifetime (Fig. 2). Data

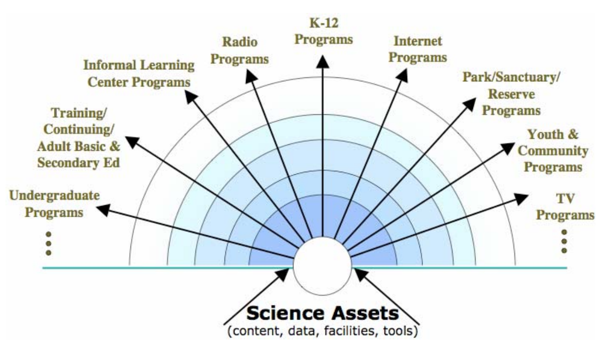

Figure 2. *Education Sector:* programs target specific education audiences. Arrows highlight flow of information from science and technology sources via intermediaries (blue rainbow) to the end audience. Figure is a synthesis of concepts from several fields (communications, education, customer service, business process control) and the authors' personal experiences.

translation and story development is the nexus of information flow from the science and technology community into these three audience sectors and their unique program sectors (Fig. 1 and 2). As such, it is positioned to promote content continuity and coherency between sectors and within a sector, thereby supporting scalability and improvements in return-on-investment. It is, however, only one part of this multi-part system, in fact, as in the Government Research Enterprise model (below), the direct audience may be an intermediary on the pathway to the ultimate target audience.

III. Academic Research Organization Model (Rutger's)

The oceanographic community is recently tasked with developing implementation plans for the future Ocean Observing Initiative (OOI) established through the National Science Foundation's ORION program. One of the largest challenges remaining for the community is to determine how education and public outreach efforts are to be integrated within the overall ocean observing system (OOS) structure. Rutgers University has been a pioneer in coastal ocean observing systems, and has a long tradition of intimately integrating education and public engagement efforts with the operations of the observatory network. Here we chronicle the development of an organizational infrastructure for the Rutgers University Coastal Ocean Observation Laboratory (RU COOL) and the Education & Public Outreach group (EPO) at the Institute of Marine & Coastal Sciences (IMCS), highlighting how these three groups work together to support the operational application of our OOS. The evolution of this model is in a formative phase and is an excellent evaluative study for the development of effective practices in EPO.

A. Case Study: Ocean Observing on the New Jersey Shelf

The RU COOL laboratory is focused on "adaptive sampling," where a network of sustained observations support directed research projects, that typically involve collaborations of several academic, commercial and government groups. The Education & Outreach group at RU is focused on the design and implementation of education programs that help scientists communicate their science to K-12 educators and their students. In 2002, RU IMCS became part of the NSF funded Centers for Ocean Science Education Excellence (COSEE) where the focus became linking scientists and educators to improve knowledge and awareness of the ocean sciences. To date, the operations center and EPO group is largely supported by private foundation and federal grants.

Collaboration between science, data management, data translation, and education and outreach has increased dramatically with each formative year of operation. While initially independent, today the groups are tightly integrated which aids in accomplishing common goals (i.e. using oceanographic data visualizations to promote ocean literacy). Figure 3 depicts the organizational structure of the Operations and Outreach groups, and shows how the two groups interact to provide oceanographic products, programs, and services to the user community.

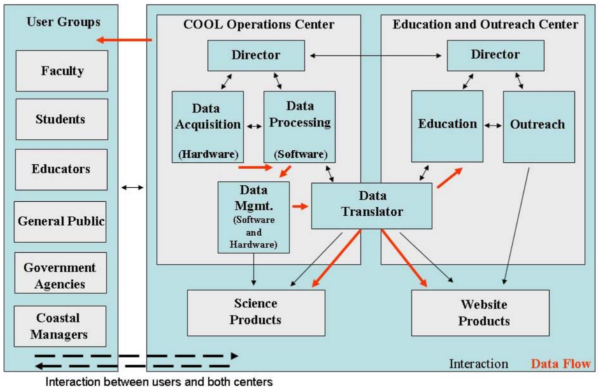

Figure 3. Organizational chart of the RU COOL Operations Center and the Education and Outreach group at IMCS

The COOL Operations Center start-of-the-art sampling capabilities are continuously upgraded as new technologies, developed by the research group, are immediately transitioned into the operational setting of the center. Raw data sets are shared with a variety of super-users throughout the U.S. for real-time backups, data archiving, and advanced product generation. Operational data products are produced in real time and posted to the Internet for use by scientists, educators, decision-makers, and the public. Website access peaks in the summer, averaging over 150,000 hits per day in 2006. Each instrument provides long-term, synoptic scale data that are an invaluable asset for researchers conducting process studies within the observing system region.

As both the EPO group and Operations Center have matured, the need for improved data products, visualizations, and delivery mechanisms for the data products increased. A Data Translator works with the leads from the data acquisition and data processing teams to develop relevant visualizations for a range of user groups (anyone from a scientist, to K-12 educator, to the media). This position fosters collaboration between the two groups, by ensuring the operations group is aware of the visualization needs of E&O efforts, and provides the E&O group with access to upcoming data products and research findings for story development. The data translator also assists the data processing team develop the data management system and new operational visualizations to ensure smooth and efficient collaboration between data archiving, retrieval, and data product delivery to user groups.

The EPO group delivers professional development for K-12 educators and coastal decision makers (municipal officials), family science programs, outreach events, and print products. The group also consults on programmatic needs of the scientists or by *brokering* service to a partner in the informal or formal education community. EPO staff members work together to
1) Assess the needs of user groups and provide feedback to data product developers (both on staff and contracted)
2) Engage K-12 and informal educators with educational design experts (e.g., curriculum developers and exhibit designers) to develop relevant education products that utilize COOL data,
3) Promote access by the media to COOL *stories* of interest to the press (print and TV/radio media),
4) Implement distribution of products and services developed (e.g., professional development programs, CD-ROMs, brochures, etc.) and evaluate the impact/success of products developed (including formative and summative assessments).

B. Elements of Success

The COOL group (both Operations and EPO) have been active members of the evolving ocean observing community. Success as a group can be attributed to a clear mission between and within each group and good communication at the early stages of program development that results from 1) regular facilitated meetings between team members and 2) close physical proximity in the working environment. All staff feels equally vested and valued in the overall center mission. From our experience with COOL, success occurs when there is a mutual stated desire and clear path for scientists, data managers, and educators to work together for a common goal of providing quality education products to the public. All parties have to believe they are equally vested in the process. Note that the user groups (defined as scientists, K-12 educators, students, general public, etc) follow an instructional design model (Gagne 1987) which provides input in terms of data needs to all three centers within the program. Innovations come from the science community who are developing new technologies and new data streams of possible use by the user groups. Educators ensure adequate user input (in form of needs assessments) and build capacity within a network of education leaders (i.e. develop implementation strategies). Finally, educators and scientists together develop and maintain collaborators and partners essential to the network (i.e. media coordination) and evaluate the impact of the data translation facility (including formative and summative assessment).

IV. Government Research Enterprise Model (NASA)

NASA designed and implemented [8] a process to effectively and broadly disseminate NASA Earth science research results with intent to improve the public's awareness and understanding of the Earth system and NASA's role in that research. The story development and translation process was based on identification, translation, and dissemination of fully vetted, publication-ready science and technology discoveries and innovations. The resulting systematic process targeted media professionals as intermediaries to the end-audience (the public) and therefore measured effectiveness in terms of these professionals' efforts.

A. Background

In 1997, before this case study, NASA funded one of the largest and most productive collections of Earth system scientists and technologists in the U.S. These individuals were engaged in scientific research and technological innovation to discover the processes, interactions, and interdependencies of the Earth's environmental system. Scientific and technical publication rates for the scientists and engineers at Goddard Space Flight Facility (GSFC)—one of the largest collections—were comparable to their colleagues at Research Class I universities in the U.S. [9]. Yet, very little of this research at GSFC or university locations was known to the public or used by educators in their classrooms, exhibits, or programs. The public affairs office at GSFC produced on average 3-4 stories

per year based on GSFC's research and technology innovations [10]. Occasionally a story would appear in local newspapers or news broadcasts. On rare occasions one would appear in exhibits at informal learning centers (i.e., science centers, museums, aquaria) or in formal classroom settings. There was no systematic mechanism to identify, translate, prepare, and disseminate engaging research results to the public.

B. The Case Study

The purpose of this study was (1) to show there are many stories of broad public interest embedded in the yearly research and innovation output and (2) to examine the ability of story development and data translation to produce large numbers of stories, promote their use among the media and educators, and provide a cost effective solution that promotes content continuity and coherency between and within communication sectors.

Previously, we described NASA's Earth science story development and data translation in terms of the products produced, audiences served, critical processes, essential skills, and required coordination and collaboration [8]. Here we focus on the results of story development and data translation in terms of stories produced, coverage achieved the media, and cost. A future publication will address use by educators, cost benefits, and promotion of continuity and coherency between and within communication sectors.

Here the engineering process improvement continuum is used to assess NASA's Earth science story development and data translation process, a small portion of the *whole system* (Fig.1). The terms input, output, outcome, and impact used here describe in-flow (input), out-flow (output), and effect of these two on the desired results (outcome and impact) of the process being improved. The direct audience for this portion of the *whole system* is the media, who are intermediaries to the indirect audience, the public. Within this context, measurement is focused on the direct audience and their actions because that is within the sphere-of-influence of the process being improved (Table I). Consequently, impact data were not collected.

TABLE I
APPLICATION OF PROCESS IMPROVEMENT CONTINUUM TO NASA'S STORY DEVELOPMENT AND DATA TRANSLATION PROCESS

Process Continuum	Definition
Input	1) All the possible stories that *could be* developed and produced based on fully-vetted, accepted-for-publication research or technology innovations 2) Manpower applied 3) Budget available
Output	Stories that *are* developed and produced
Outcome	E*xtent* the produced stories are *used* by the media and *appear* broadly society (coverage achieved by the media)
Impact	*Extent* of indirect audiences that heard, read or saw the story

Over the first five years inputs rose and then fell while output and outcome increased dramatically (Fig. 4). The input in terms of manpower and funding peaked in Year 3. A count of potential stories was not collected during the study period. A slow increase in total stories is likely since this trend was observed for the period immediately preceding this study [9]. Output exhibited a 10-times increase in the number of stories

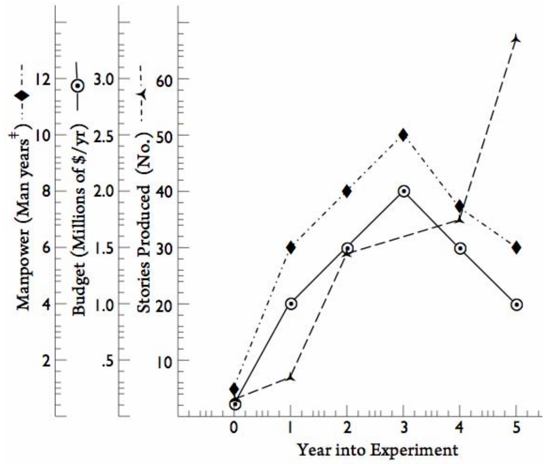

Figure 4. Input and outputs of NASA's Story Development and Data Translation capability. ‡ = Estimate of manpower does not include civil service manpower, which was constant from Year 1 through 5 at about twice the Pre-experiment level.

produced for the media (Fig. 4) and outcome as coverage achieved by the media improved from mainly regional and local markets to national and global markets (Fig. 5).

The 10-times increase in stories produced can be partly explained by the increase in funding (Fig.4). The influx of funds in Year 1 and 2 resulted in a significant increase in the number of stories (3 vs. 29). The team dedicated to Earth system science can explain this improvement. However, it is not the sole explanation since the budget and manpower followed a totally different pattern, increasing in these early years and then declining to the original level in later years.

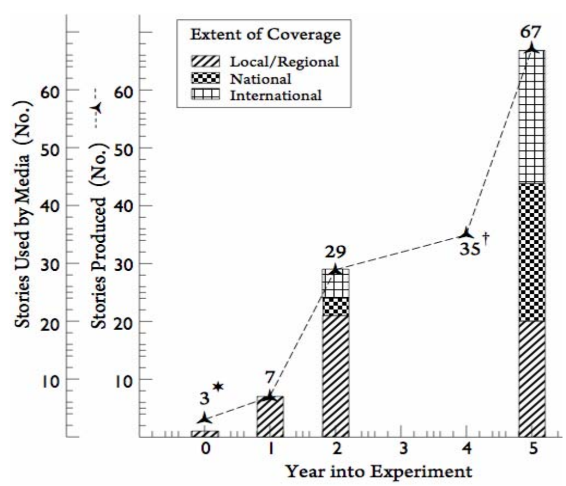

Figure 5. Usage of stories and extent of usage by the media. * = Number of stories produced. † = Detailed breakdown of stories is not available.

The peak in budget input did not coincide with the peak in output, stories produced. Moreover, when the first and last years are compared, budget and staffing were nearly the same, yet stories produced was 10-times greater (Fig. 4). The step-function pattern of stories produced, coupled with the patterns for budget and staffing strongly suggest a threshold-response relationship between output and these input factors.

Going from essentially no organized team—no dedicated staff, non-optimal visualization and illustration tools—to an

organized team yields an improvement in output of stories. Likewise, the plateau and continued increase in stories produced with declining budgets agrees with the prior observation [8] that a story development and data translation process exhibits a significant spin-up period. During this period, key processes, effective working relationships, and **trust** are established within the team and between the team and the story sources (i.e., scientists and technologists) and story consumers (i.e., broadcasters, science writers, journalists). Outcomes, as measured in Table I, improved significantly over the 5 years of the study. To quantify the extent that stories appeared in our society, each story was evaluated using the following factors: did media use the story; number and size of markets where story appeared, type and diversity of venues where story appeared, geographic distribution of venues that used story. Using this information stories were sorted into one of three coverage categories—local/regional, national, or international (see Table II for an example).

The 10-times increase in stories produced coupled with their expanded coverage over the five years suggests that something more than improvements in team efficiency was at work (Fig. 5). Improved efficiency cannot explain the change in distribution of coverage from a few small local markets to many national and global markets with many different venues.

TABLE II
EXAMPLE OUTCOME FROM ONE STORY IN YEAR 5 OF NASA'S STORY DEVELOPMENT AND DATA TRANSLATION CASE STUDY

Story: Satellites Reveal Mystery of Large Change in Earth's Gravity Field Bin: International	
Venue Type	Story Appearance[§]
Radio	National Public Radio, BBC Radio *The World*-several segments, Good Morning Scotland Radio Program, BBC Radio, Rush Limbaugh Radio Program,
TV	CNN-multiple discussions, National Geographic News, MSNBC, Australian Broadcasting Corporation, Iranian News, CNN Europe, National Geographic Channel
Newspaper US:	Philadelphia Inquirer, Atlanta Constitution, New York Times, Washington Post, Seattle Times, Miami Herald, New York Post, The Ledger-Enquirer (Columbus, OH), Times Union Newspaper (Albany, NY), Aberdeen News (South Dakota), Florida Today
Intl:	Ottawa Citizen, The Straits Times (Singapore), The Huddersfield Daily News (U.K.), Sydney Morning Herald (Australia), The Scotsman (Scotland), London Standard Weekly, London Daily Telegraph
News Service	Nature News Service, UPI, Press Association of Britain (like UPI), Bloomberg News, Knight-Ridder Newswire
Website	Space.com, BBC News On-line, Spaceflight Now, Ananova, Cosmiverse.com, Physics Web, Sky.com, Co-posting on newspaper, TV, and radio websites
Longer Format	New Scientist, US News, Astronomy Magazine, Time Magazine, Science News, Science Daily

[§]Partial listing within a few days after story release.

Not only are more stories produced, the stories were more desirable to the media. By Year 2, unlike the pre-experiment period, media professionals were using all of the stories produced. By Year 5 stories were used more often, appeared in a wider array of venues, and appeared as longer format, more prominent stories and features. Media professionals increasingly looked to this group as a *trusted* source of high quality stories and supporting materials [11]. Several factors contribute to this increase in outcomes: improvements in the story packages, creation of a positive reputation, and posting of stories to news services and clearinghouses used by science writers.

First, over the 5 years both the storylines and the composition of the story packages improved significantly. In Year 1, story packages had two main elements, a developed storyline and still images. In Year 5, packages had more elements (scientific visualizations, animated illustrations of abstract concepts, *in-the-field* footage and live interviews) with more formats and image resolutions targeted to different media outlets (newspapers, magazines, analog and digital TV, Internet, radio). Broadcasters who would not use the stories produced in Year 1 used these because the packages contained the elements they needed for an effective broadcast [12].

Second, in Year 5 a positive reputation was established with the media who sought these packages because of their engaging stories; effective images, visualizations, and illustrations; and timeliness and reliability of product release [12]. Indeed, broadcasters and journalist were requesting to be notified of upcoming stories, and scientific journals (e.g., Science) called asking for help with public release of research publications sponsored by NASA. [11,12].

Third, by Year 5 news services and clearinghouses were posting the stories and redistributing them to their clients. National offices of broadcast corporations (e.g., NBC, CBS, CNN) were redistributing stories to their local affiliates across the U.S. [12]. Stories began appearing in Science News and Science Daily, publications whose primary audience is science writers (see Table II).

Together these 3 factors (more robust story packages, reputation for quality and reliability, and redistribution by third parties) reflect improvements in effectiveness of the team and go a long way toward explaining the remarkable increase in coverage observed over the 5 years of the case study.

V. INSIGHTS FOR OCEAN LITERACY

For a person to become ocean literate, they must first want to learn about the ocean and the environment around them. They must care enough about the world and the ocean in particular to be concerned about the future of the ocean, coasts and Great Lakes. They must understand how closely tied their personal health, wealth and well-being is to the health and well-being of these water bodies. This desire to learn, to care, and to understand must be sustained for a lifetime, because ocean literacy is fleeting. If not sustained, it will be lost.

Here we have addressed the supply of engaging stories that can be use to capture attention and begin the journey to learning, caring and understanding. The stories themselves are necessary but not sufficient to capture attention; they must work in consort with the efforts to develop motivation to learn, to care and to understand. This supply of stories can be used to invigorate those who already care, already want to learn, and already have some understanding. More importantly though, these stories when placed in the right hands can capture the attention of those who have not been moved to care, to learn, or to understand. For this to happen the stories must be many and varied and they must be known to and be useable by those who

will convert them into polished and captivating learning materials. They must be everywhere in our society, in a large number of different settings, for people of all ages and demographic groups. And finally, they must be anchored in things that people care about and are familiar to them.

The story development and data translation case studies discussed here are mechanisms to provide this constant supply of new stories needed to achieve ocean literacy. They are a part and only a part of the very first step in that process. They address efforts to provide accurate information in a way that education and communication professionals can readily repackage in engaging ways for their audiences, moving them a small step at a time toward ocean literacy.

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[9] B. Meeson, personal communication with Louis S. Walter who compared productivity of GSFC scientists and technologists with their university colleagues.

[10] B. Meeson, personal communication with GSFC senior TV producer who compiled story information for internal management briefings.

[11] B. Meeson, personal communication with senior story developer who routinely received requests from broadcast colleagues to be notified of upcoming stories.

[12] B. Meeson personal communication with story developer, TV producer, and multi-media producer who routinely spoke with media professionals about story releases.

